Design of a New-style and High-stability LD Drive Power Supply

Aiwen Zhang, Min Zhou, Zhiping Cai,*Huiying Xu
Institute of Opto-electronic Technology
Department of Electronic Engineering of Xiamen University
Xiamen, China
E-mail: huiyingxu@126.com

***Abstract*—This paper describes the design of a new-style and high-stability semiconductor laser diode(LD) linear drive power supply, which is able to drive 100mW to 1.8W laser diodes and the output current can be continuously adjustable from 0A to 2.5A. The current stability obtained in the LD driver circuit is superior to 0.3‰. In the design we have innovative ideas of the soft-start circuit, the current-limiting circuit with special rated-current setting function, the surge ripple prevention and filter circuit，especially enhance the stability and security of the power drive system. Such design will be found wide applications in the fields of teaching, scientific research and production.**

Keywords- semiconductor laser diode; power supply; stability

I. INTRODUCTION

Semiconductor lasers have not only a high degree of monochromaticity, coherence, directionality, and brightness like general lasers, but also have advantages such as a small size, light weight, direct modulation, and low price. So they have been more and more widely used in national defense, scientific research, medical, optical communications and other fields [1, 2].

LD is the current drive device, the operating life and work characteristics depend largely on the performance of the drive power supply [3]. Because semiconductor laser is a device of high power density and with high quantum efficiency, the capability of suffer from electric shocks is very poor, micro-current fluctuation will cause a great change of optical power and device parameters(such as laser wavelength, noise performance), and these changes directly endangering the safe use of LD. So in practice application, the performance and security requirements of the drive power are highly demanded. Weakness in design of drive power will do harm to LD or even damage it, therefore, design a drive power fit for the LD technical requirements with stable performance and reliable operation is quite necessary[4,5,6,7]. In our design of the drive power, we focus on the safe and effective protection of the LD, such as soft-start circuit, surge prevention circuit, and current-limiting circuit[8]. We use a 635nm LD whose type is G0331 in experimental testing, the result can meet the LD requirements, and it can work with high security and stability.

This work was supported by the key project of Fujian Province Science & Technology Foundation(2004 HZ 01-1-3) and Fund of National Engeering Research center for Opto- electronic Crystalline Materials (2005 DC 105003).

II. SYSTEN OVERVIEW

A. Design of overall system

The whole system contains two part--power supply part and current drive part, whose configuration is shown in Fig. 1. As we can see in Fig.1, we creatively design a two-stage soft-start circuit is designed to restrain the surge effectively when we turn-on and turn-off the power, another good point should point out is when the circuit is over-current, the current-limiting circuit will make the circuit work at the rated-current rather than cutting it down, so that the LD can work continuously and effectively.

B. Design of power supply circuit

In this part, a high-voltage input of 220VAC is transformed into a low-voltage DC output to offer the power supply for the current drive circuit. As is shown in Fig. 2, 220VAC was transformed to a low voltage 12VDC by a transformer, bridge rectifier and filter network. Then it will be sent to the adjustable regulator LM338 to get a adjustable and stable output whose value is decided by formula(1).

$$Vo = \left(1 + \frac{Rp1}{R2}\right) \times Vref \tag{1}$$

In formula(1), Vref is a constant value equals 1.25V.

As we can see in Fig. 2, Fu is a fuse that is used to protect

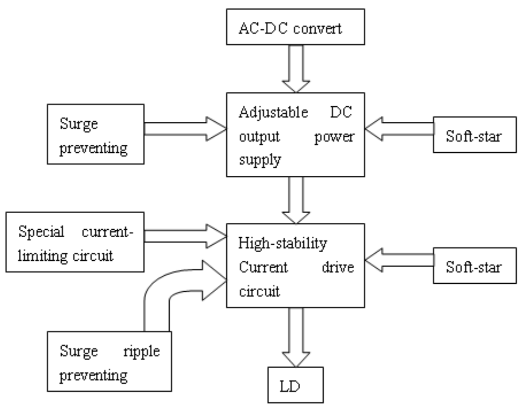

Figure 1. System design diagram

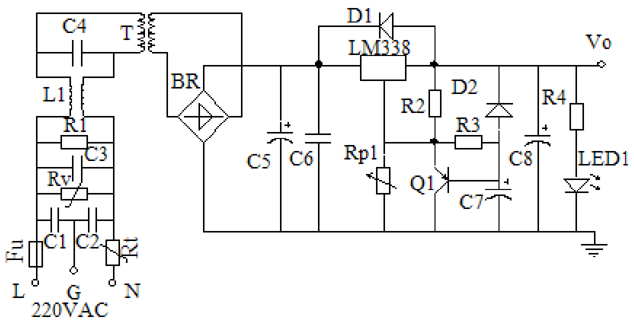

Figure 2. Adjustable power supply circuit

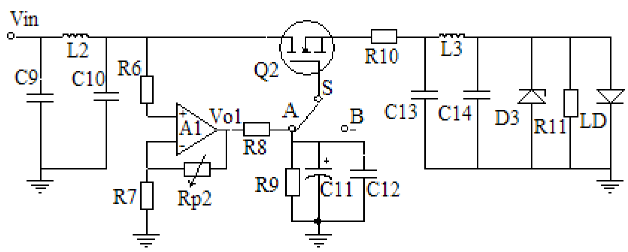

Figure 3. Current source and surge ripple prevention circuit

the circuit from over-current, Rt is a thermistor can limit the inrush current to avoid the fuse be damaged ahead of time, Rv is a voltage dependent resistor used to absorb the voltage surge. L1, C1, C2, C3, C4 and R1 compose a electromagnetic interference(EMI) filter; L1, C1 and C2 can restrain common mode interference while C3 and C4 are used to restrain series mode interference; moreover, when we cut down the power, C3 can discharge the electricity by R1, so we can avoid the input port L and N charged with electron when we turn off the power. Q1, Rp1, R2, R3, and C7 compose a soft-start circuit. When we turn on the circuit, because the voltage of capacity C7 couldn't be changed suddenly, the voltage on base electrode of transistor Q1 is at a low potential, therefore Q1 will work in the saturated zoom, so Rp1 will be a short circuit, the output Vo is about 1.5V; along with C7 is charged, Q1 will quit the saturated zoom gradually, the output Vo is increasing gradually, after the charging of C7 is completed, Q1 will work in the cut-off zoom, the output Vo will reach it's setting-value, the speed of slow start is decided by R2 and C7. What's more, C5 can restrain the voltage ripple and C6 is used to eliminate the parasitic shock while C8 can improve the transient response of the regulated power supply; diodes D1 and D2 can protect the circuit when C8 leaks electron or the adjust port of LM338 is a short circuit. By the way, LED1 is a Indicator of the output voltage.

C. Design of current drive circuit

The output Vo of the power supply part will be converted to a linear and adjustable current ranged from 0A to 2.5A. We have innovative idea of a two-stage soft-start circuit to protect the LD effectively when we turn-on or turn-off the power, we also design a special current-limiting circuit who can make the LD work at the rated-current when the circuit is over-current. What's more, surge ripple preventing and filter circuit are design to improve the reliability, stability and security of the power supply.

1) Current source ,soft-start,, surge ripple prevention and filter circuit

As is shown in Fig.3, L2, C9, C10 and L3, C13, C14 compose two π type filter circuit separately posited in the input port and output port of the circuit, they can effectively restrain the electromagnetic interference.

R6, R7, Rp2 and operational amplifier A1 compose a proportional amplifier with output:

$$Vo1 = \left(1 + \frac{Rp2}{R7}\right) \times Vin \qquad (2)$$

Here Vin is the output Vo in Fig.2. As we all know, MOSFET is a voltage-controlled current component, we can control the drain current by adjust the grid voltage, therefore, MOSFET Q2 and proportional amplifier A1 compose an adjustable current source who can adjust the current through Rp2. As the LD is quite sensitive to the current, we need to increase the current on LD; this function is achieved by soft-start circuit. The soft-start function is completed by R8, R9 , C11and C12, because the voltage on capacity can't be changed suddenly, the voltage on grid of Q2 can't be changed suddenly too, so the output current will increase or decrease gradually when we turn-on or turn-off the power. Zener diode D3 and R11 are used to absorb the surge current to protect the LD. S is a relay switch, usually S connect to A, but in protection mode, it will connect to B, this will be explained in the current-limiting circuit.

2) Current-lmiting circuit with special rated-current setting function

Although the soft-start circuit can eliminate the impact of high-frequency current, but it can't effectively prevent DC or low-frequency over-current, so current-limiting circuit must be designed to protect LD from overload[9]. The over-current protection function of traditional drive power[10,11] are too regular, they will cut down the output when it is over-current, therefore the LD couldn't work continuously if necessary. So we creatively design a special current-limiting circuit which can make the circuit work at a setting-current(usually the rated-current) when it is over-current.

As is shown in Fig.4, R10 is a precision resister which is used to sample the drive current of the LD; A2 and A3 are both proportional amplifier, A4 is a subtractor, A2, A3 and A4 compose a current-voltage convert circuit who can convert the sampling current single to a voltage with high precision. As the input ports are non-inverting terminals, the input resistor is very high, A2 and A3 have the same characters, so they can restrain the temperature drift effectively, and the ability of anti-common-mode interference is very strong. We need to set R12=R14, R15=R16=R17=R18, the output of A4 is described by formula(3).

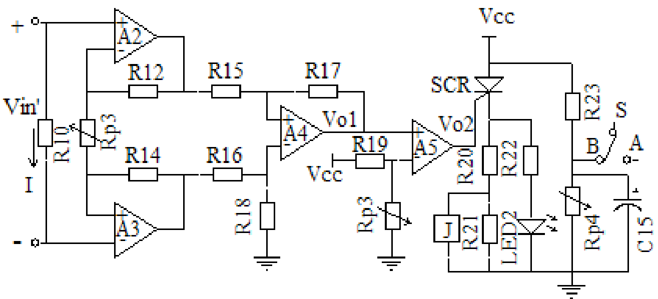

Figure4. Current-limiting circuit with special rated-current setting functions.

$$Vo1 = \left(1 + \frac{2R12}{Rp}\right) \times R10 \times I \tag{3}$$

The output Vo1 of A4 is send to a comparator A5 to compare with a reference voltage which decided by the protection-current. The output Vo2 of A5 will control the gate of a thyristor SCR. According to formula(3), when the LD is over-current, the output of A5 is a high voltage, so the SCR will turn on, the relay will connect B with S, then the circuit will work in protection mode. We can set the voltage of B by Rp4 so we can set the output current at the rated-current. LED2 is used to show weather the circuit is work in protection mode.

III. TEST OF EXPERIMENT AND RESULT ANALYS

A. *Test of soft-start function*

We connect the laser diode whose type is G0331 to the output port of drive power supply and we use an oscilloscope whose type is TDS2024 to record the result. It is clear from the Fig.5 that: After we turned on the drive power, LD work voltage tardily increases from zero to 2.3V by 4.5 seconds delay. Then we turn off the power, we can see the voltage decrease slowly too.

B. *Test of surge prevention*

We change the oscilloscope to AC mode and set the scanning period at 1.00 second; We adjust the drive current on the maximum value of the LD which is 0.8A, then we turn on

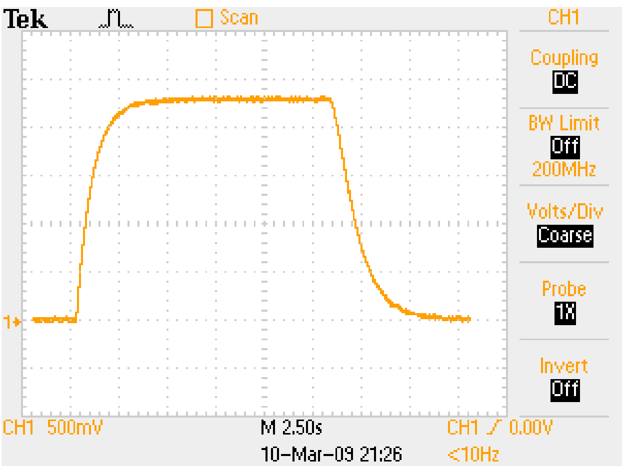

Figure 5. Curve of soft-start test..

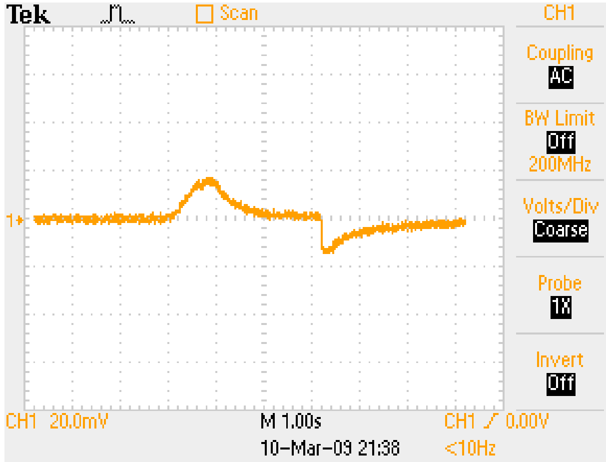

Figure 6. Curve of surge prevention test.

and turn off the drive power quickly, looking at the curve we record by the oscilloscope in Fig.6, we can see that the surge voltage is quite low, it is less than 20mV. We do the on-off convert time and time again, and the LD could work smoothly. It shows that this drive power supply has a high-efficient surge prevention function to enhance the stability and security of the drive system.

C. *Test of output ripple*

We adjust the drive current from the threshold 0.5A to the maximum value 0.8A, we found that the output voltage ripple is always less than 0.1%. Fig.7 shows the output voltage ripple when the drive current is 0.8A and the voltage across the LD is 2.3V. We can see the peak-peak value of the voltage ripple is 1.6mV, we do the test near to some computer powers and switch powers, and the ripple is still less than 0.1%. This means that the drive power has a high-efficient anti-interference function.

D. *Test of over-current protection*

Fig.8 can help us to understand the special over-current protection function. We remove the LD and connect the drive power to an equivalent load whose resistance is 2Ω. We set the protection current at 1.0A by Rp3 in Fig.4; we also set the

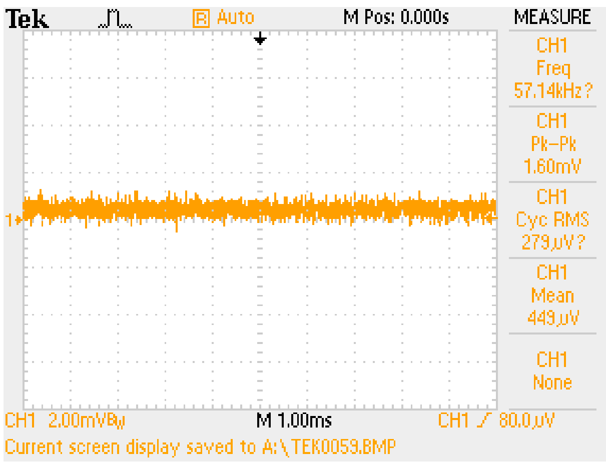

Figure 7. Test of output ripple voltage.

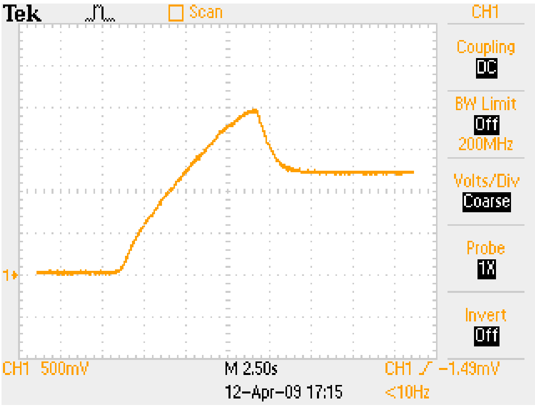

Figure 8. Test of over-current protection

rated-current at 0.6A by Rp4 in Fig.4, then we adjust the output current by Rp2 in Fig.3. As is implied in Fig.8, once the current exceed the protection value(1A), the output current will decrease to the setting value(0.6A) which is usually the rated-current.

E. Test of current-stability

An important parameter of LD drive power is current-stability. It is calculated by repeated measurement in certain time, it can described by formula(4).

$$P = \frac{average\ value - calibration\ value}{average\ value} \quad (4)$$

The test data are recorded in table I. we can calculate that the average value is 800.233mV and the calibration value is 800mV. according to formula(4), we know the current-stability is 0. 29‰.

TABLE I. CURRENT-STABILITY MEASUREMENT

Time(min)	1	3	5	7	9	11
Current(mA)	800.00	800.08	800.16	800.22	800.14	800.20
Time(min)	13	15	17	19	21	23
Current(mA)	800.16	800.26	800.21	800.24	800.11	800.18
Time(min)	25	27	29	31	33	35
Current(mA)	800.09	800.28	800.14	800.19	800.15	800.39
Time(min)	37	39	41	43	45	47
Current(mA)	800.41	800.29	800.43	800.27	800.35	800.22
Time(min)	49	51	53	55	57	59
Current(mA)	800.16	800.24	800.53	800.28	800.25	800.36

F. Test of optical power

Joint the LD of type G0331 to the output port of the drive power and control the LD temperature to remains 15 □, then we adjust the work current slowly, we got the output at the threshold current of 0.5A, and got the maximal optical power 700mW at the current of 0.8A. And the output wavelength is 635.1nm.

IV. CONCLUSION

The LD drive power supply we design can effectively drive the laser diodes whose type is G0331. The EMI design and the surge prevention enormously improve the stability and security of the drive power supply whose current output is adjustable from 0A to 2.5A, the special over-current protection function make the LD work continuously if necessary. This new-style and high-stability LD drive power will found wide applications in the fields of teaching, scientific research and production.

REFERENCES

[1] WANG D, LI X Q, "New progress in semiconductor lasers and their applictions," Optics and Precision Enginneering, vol. 9, pp. 279-283, June 2001. (in chinese)

[2] LIU Y, JIAO M X, "The Design of Current Supply for Diode Laser," Applied optics, vol. 6, pp. 9-11, May 2005. (in chinese)

[3] HUANG D X, LIU X F, "Laser diodes and the applications of laser diodes," Beijing: National Defence Industry Oublishing Company, pp. 255-256, 1999.(in chinese)

[4] Thompson M T,SCHLECHT M F, "High power laser diode driver based on power converter tecnology," IEEE Trans on Power Electronics, vol. 12, pp. 46-52, January 1997.

[5] LI G, CHEN J X, ZHANG Y,et al. "Power supply of high-power diode laser," chinese Journal of Quantum Electronics, vol. 20, pp. 30-34, February 2003.(in chinese)

[6] LIU CH., "Design of stable power pulse source for semiconductor lasers," Semiconductor Optoelectronics, vol. 25, pp. 235-237, 2004.(in chinese)

[7] JIN Y H, XU W H,YANG M W, et al. "Study of improvement of the driver of continuous semiconductor laser," Optoelectronic Tecnology, vol. 25, pp. 44-47, March 2005.(in chinese)

[8] Sliney D H, "Laser safety concepts are changing," Laser Focus Word, vol. 30, pp. 185-192, 1994.

[9] MAO H T, LIN Y H, ZHANG J Lg, FENG W, CHAI X L, et al. "A Design of Driving Source for Semiconductor Laser," Journal of Xinxiang Teachers College, vol. 19, pp. 21-23, September 2005.(in Chinese)

[10] YU F X, PANG D Q, AI X, "The Design for High-power Diode laser driver" Applied Laser, vol. 20, pp. 257-260, December 2000. (in Chinese)

[11] WANG J D, LIU H L, WANG Y C, "Novel protective circuits of diode laser," Applied Laser, vol. 26, pp. 119-121, April 2006. (in chinese)